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ABSTRACT

This report describes the Applied Mathematics Laboratory (AML) operated by the Department of Mathematics at Towson State University, Maryland. AML is actually a course offered to selected undergraduates who are given the opportunity to apply their skills in investigating industrial and governmental problems. By agreement with sponsoring organizations, AML undertakes research projects of a mathematical nature whose analysis, solution, and exposition require the substantial involvement of a team of students and faculty members for an academic year. Evidence of program effectiveness includes the following facts: AML is recognized in the business community in the Baltimore metropolitan area; corporate responses have been uniformly favorable; and AML received the Distinguished Program Award from the Maryland Association of Higher Education in 1984. Recommendations considered when setting up such a project included: contract all year-long projects in the spring for the next academic year; assess the same fee for each project; have a tenured and self-confident faculty member as the primary director; and have an administrator who can interact well with industrial and business people. An appendix lists AML projects from 1980 through 1989. Contains 3 references. (Author/SM)

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AASCU/ERIC Model Programs Inventory Project

The AASCU/ERIC Model Programs Inventory is a two-year project seeking to establish and test a model system for collecting and disseminating information on model programs at AASCU-member institutions--375 of the public four-year colleges and universities in the United States.

The four objectives of the project are:

- To increase the information on model programs available to all institutions through the ERIC system
- To encourage the use of the ERIC system by AASCU institutions
- To improve AASCU's ability to know about, and share information on, activities at member institutions, and
- To test a model for collaboration with ERIC that other national organizations might adopt.

The AASCU/ERIC Model Programs Inventory Project is funded with a grant from the Fund for the Improvement of Postsecondary Education to the American Association of State Colleges and Universities, in collaboration with the ERIC Clearinghouse on Higher Education at The George Washington University.

ABSTRACT

The Applied Mathematics Laboratory is operated by the Department of Mathematics of Towson State University, Towson, Maryland. The Applied Mathematics Laboratory is actually a course offered to selected undergraduates who are given the opportunity to apply their skills in investigating industrial and governmental problems. The Applied Mathematics Laboratory, by agreement with sponsoring organizations, undertakes research projects of a mathematical nature whose analysis, solution and exposition require the substantial involvement of a team of students and faculty members for (usually) an academic year. The sponsor submits a fee for the research project to Towson State University to cover the costs of services, equipment, and faculty and secretarial time.

THE APPLIED MATHEMATICS LABORATORY

at

Towson State University

In 1980 the Department of Mathematics at Towson State University established its Applied Mathematics Laboratory, an innovative approach to teaching talented students how to apply mathematics to solve industrial problems. In the program, teams of students, under faculty supervision, undertake a mathematical research project for a sponsoring agency. Since its inception the Applied Mathematics Laboratory has completed research projects for seven sponsors.

The Applied Mathematics Laboratory (AML) is actually a course in which selected undergraduate students are given the opportunity to apply their mathematical skills to a wide variety of problems. They work on research projects which are provided by corporations and governmental agencies in the Baltimore metropolitan area. After reaching agreement with a sponsor, the AML assigns an appropriate team of students and faculty to investigate the project. The team is chosen especially to meet the challenges of the sponsor's problem and is assigned to that problem for either a semester or an academic year, whichever is appropriate. The sponsor submits a fee for the research project to Towson State University to cover the costs of services, equipment, and faculty and secretarial time.

Problems are accepted if they have educational value to mathematics students, if there is a reasonable chance of a successful resolution, if they can be handled within the time frame of an academic year and if the sponsor is willing to allocate liaison time when appropriate. Problems which are most suitable involve model formulation, analysis, and verification; such problems usually have an important computing component.

The Applied Mathematics Laboratory at Towson State University is quite unique, even though similar programs do exist at a few other institutions in the United States. Comparable programs have been established at the Claremont Graduate Schools, Harvey Mudd College, Clemson University and Rensselaer Polytechnic Institute. However, these programs rely heavily on graduate students and post-doctoral fellows as project team leaders. Towson State University is a liberal arts institution with no graduate programs in applied mathematics, and its Applied Mathematics Laboratory is the only successful program of its type in which the teams are composed entirely of undergraduates.

The students that participate in an AML project receive benefits beyond any educational experience offered by traditional university courses. The experience is invaluable for showing them the rigors, frustrations, and pleasures of research. It provides an opportunity for a student to use the theoretical material from the classroom, new material from personal research,

and the information and expertise of other team members in a cooperative educational setting. The processes of understanding the problem, assisting in the mathematical formulation, developing necessary skills, obtaining information and sharpening expository skills are as important as the actual solution of the problem. In addition, the close working relationship that students have with faculty allows a personal dimension to their education which both parties enjoy. For our students this is a unique experience in learning: how to work with others, how to express complicated ideas clearly and confidently (in written and in oral form), and how to use the many skills and resources available to them.

There are also benefits for the faculty participants. The opportunity to work closely with a small groups of talented students is always welcome, of course. Furthermore, since most faculty members were trained as pure mathematicians, this experience gives them the chance to see the relevance of their knowledge and then to bring this experience back to the regular classroom. In addition, most sponsors agree that the faculty members may publish papers about the applications of mathematics to the project, provided proprietary information is excluded.

The entire University also benefits from the work of the AML with companies in the Baltimore metropolitan area. The reputation of Towson State University as a vital resource in the community is enhanced by these efforts. Previous sponsors have asked the University to expand its cooperation by providing internships and research personnel for them. This unique program also helps the University attract outstanding mathematics students.

This novel method of teaching applied mathematics has gained the attention of the Mathematical Association of America and the Society of Industrial and Applied Mathematics. In fact, in its October, 1980 SIAM News, the Society made specific mention of the Towson State course. The development of the Applied Mathematics Laboratory was subsidized by the National Science Foundation through a Local Course Improvement Grant. Recent sponsors include the Westinghouse Electric Corporation, Union Trust Bank, Citicorp, A.A.I. Corporation, Blue Cross-Blue Shield of Maryland, and the Comptroller's Office of the State of Maryland.

Recommendations

It would be irresponsible to imply that a program of this sort has no difficulties. There are some aspects of the Applied Mathematics Laboratory which should be kept in mind when setting up such a program.

All year-long projects are contracted in the spring for the next academic year. This is essential for several reasons. First of all, we want to able to invite students to participate before the registration for the fall semester in which the research is to begin. Since we invite students based on both their ability and the relevance of their course work to the kind of mathematics we expect to use in the research, it is best to know what the problem is before invitations are issued. Faculty schedules are also prepared in the spring for the following fall. Since the director of the project is allowed a two course reduction from the usual classroom course, staffing courses can be tricky. Also, the directors are asked to give high priority in the summer to the preliminary work (reading, consultation with the sponsor, data preparation, bibliographies, etc.). Summer school schedules are also affected.

A firm recommendation is that the same fee be assessed for each project. It should cover the expenses of the project and for the necessary replacement of supplies and equipment necessary for successful continuance of the program. The first bill (for half the fee) is sent out after the first semester interim report is presented to the sponsor. Therefore, it is a good idea to have some funds available as "start-up" money. Generally, project directors are given a summer stipend equivalent to the pay for a usual summer course load. The AML is therefore funding the preliminary research period before students have begun their work. In addition, there is frequently a need for books, equipment and secretarial help at the beginning. After the first contract, this difficulty resolves itself, since there is a reserve of funds from each semester to at least the end of the next.

Directing a project is hard work. It exposes the faculty members to pressures that they are not used to and some may feel vulnerable leading a team. It is advisable to have a tenured self-confident faculty member as the primary director of a project. Junior faculty should be appointed to the co-directorship and after gaining the experience (and tenure, hopefully) should be expected to take on the primary responsibility in another project. For the purpose of evaluation of faculty for promotion and tenure, the university faculty and administration should be strongly encouraged to see the direction of a successful AML project as a form of research.

The administrator of the AML should be given some reduction in teaching load in the spring to allow for the search for a suitable project. All expenses associated with this are passed onto the client in the standard fee. The administrator should be the type of person who can interact well with industrial and business people. Frequently, the vice-president of a bank can propose a problem that has no real mathematical content. Some times it is wise to explain that the problem can best be handled by an accountant. Sometimes the administrator of the AML can extract a mathematical problem from a proposal and sometimes not. It is always necessary to be helpful and non-condescending. Fairly often, the problems are inappropriate because they require the actual collection of data via survey or extensive culling of government documents. This is a waste of students' mathematical talents. Suggestion should be made

immediately that the sponsor get the data before the students arrive on the scene in the fall. If the faculty director can help to direct the collection of relevant data, so much the better. But be warned: data rarely are quite as available as they appear to the sponsor.

The administrator must see to it that the team keeps to a realistic schedule so that the necessary tasks are completed by the end of each semester. This means that writing and oral presentations take place throughout the semester. As students learn preliminary material, they should be writing it up for possible inclusion in the report. This should be corrected and improved as they go along. Their oral presentations to the team should be judged for clarity and style from the beginning and often. Written and oral work account for about 30% of the course. The administrator should help the directors understand how to direct the students to finish tasks in a timely and effective manner. Rushing to write the report, preparing students for oral presentations to the sponsor, and getting results at the last minute are frustrating and prone to produce errors and shoddy output. Students are taking their final examinations in their other courses at this time and can get quite overwhelmed.

A handbook which was prepared for the AML has been very helpful in the orientation of all team participants. Sponsor liaisons, directors and students are given copies at the beginning of their commitment to the project. Forms used to evaluate oral reports, confidentiality agreements, and other pertinent information are available from the start via the handbook.

While students earn three credits per semester for the AML, they must commit more time than that implies. Students who hold part time jobs and take a full load of other courses should not be encouraged to participate. One option, of course, is to offer more credit. At Towson State, it was decided that the AML should not substitute for traditional and essential core courses or electives that would be important for the major.

The AML has found that teams of about six junior or senior students and two faculty work best. On several projects, one or two of the students were majors in disciplines other than mathematics. In each case, they were a great help in dealing with the vocabulary and methods of the sponsor. We have used majors in accounting, computer science and physics most often. We insist that the team members have completed the university's required writing course with a good grade. Although students who enroll for the first semester are not obligated to continue for the second semester, most projects have a majority of team members opting to stay on. Clearly, that is very desirable. The AML director uses the January interim holiday to help newcomers read and understand the work that took place before. The interim report is invaluable for this.

The directors should not solve the problem for the team. This is tough, because the directors' names are associated with the project. They feel their reputations are involved. However, a skillful director will guide the students by providing relevant reading material, allowing some creative guessing at possible solutions, and ultimately stepping in to prevent time-consuming, unproductive work. The AML experience at Towson State has led us to trust the students we have chosen to come up with some very good ideas. They may not be able to follow through on all of them, but they are surprisingly good beginnings.

The AML at Towson has an advisory committee comprising the administrator of

the AML, a past director of a project, at least one past sponsor and several other community leaders from business and industry. The group meets about twice a year and helps the AML keep a high profile in the community. Resources of the advisory board can vary from the actual suggestion of projects to the donation of equipment and expertise.

Confidentiality of the sponsor's business must be maintained. The AML uses a state-approved form to assure that all people involved in any way with the project understand the need for confidentiality. Faculty who would like to publish articles based on the research associated with these projects are required to contact the sponsor and secure permission. If proprietary information is omitted, this usually poses no problem.

The sponsor has responsibilty in the project even aside from dreaming up the problem and footing the bill. It is essential that the sponsor understand that the AML is not a consulting service. It is an educational enterprise. While the team will make every effort to solve the sponsor's problem, the most that can be promised is that the problem will be thoroughly investigated. The sponsor must assign at least one liaison person to be available to the director. Students are asked not to call the sponsor unless specifically invited to do so. The AML should not be a nuisance. However, there are questions from the start of the project to which the director must have answers. Data are needed and the context of the problem in the business of the sponsor should be clearly explained. The AML encourages the sponsor to invite the team for at least one on-site visit at the beginning. This is usually easy to arrange and helps the espirit de corps considerably. The liaison person should attend at least one oral presentation in the middle of each semester. This assures that the team gets feedback before it is too late to change course or to correct misunderstanding. Needless to say, the liaison should arrange for others in the company to attend the end-of-semester presentations, preferrably at the site.

The rewards to students and faculty outweigh the difficulties, of course. The satisfaction we get from seeing the problem successfully attacked, the students gaining poise and skills, and the sponsor happy with our presentation is invigorating.

Evidence of Program Effectiveness

Since its inception in 1980, the Applied Mathematics Laboratory has become a successful program that is recognized in the business community in the Baltimore metropolitan area. The AML has now conducted research projects for five corporations and two governmental agencies. Perhaps the best practical evidence of the program's success is the continuing ability of the AML to find agencies willing to sponsor projects and pay the substantial fee.

The effectiveness of the program has also been reflected in the responses of the corporate executives of the sponsoring agencies. These responses have been uniformly favorable. In particular, the oral presentations have brought high praise. In one instance, the sponsor actually hired two team members who were graduating seniors.

The AML has had a dramatic impact on the students who have participated in

a research project. Most noticeable has been the marked increase in expository skills. The students generally have felt that the program greatly enriched their undergraduate experience.

Finally, it is worth noting that the AML received the Distinguished Program Award from the Maryland Association for Higher Education in 1986.

Conclusion

The AML model for industrial-university partnership has been successful because Towson State has dedicated faculty willing to do the work. The students who have been team members have gained poise, self-confidence, satisfaction and mathematical skills beyond what we believe is possible in any other setting we could devise. Those interested in receving the brochure, the handbook and other relevant materials should contact:

The Applied Mathematics Laboratory
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Appendix I
AML Projects, 1980-1989

1980-81 STUDENT HOUSING AT TOWSON STATE UNIVERSITY
SPONSOR: Towson State University
Directors: Dr. Ohoe Kim
Dr. Yen Fook Chang

The project was to develop a mathematical model that would predict the demand for dormitory space from 1981 to 1992, in order to help the university determine a course of action regarding additional housing facilities. The study played a major role in obtaining the state's approval for the construction of a new dormitory facility.

1982-83 OPTIMAL TEST STATION LOADING
SPONSOR: Westinghouse Electric Corporation
Electronic Repair Center
Mr. George Coletta
Mr. Tony Krause
Directors: Dr. Coy L. May
Mr. Howard Kaplon

The project was a study of the repair process at the Electronics Repair Center. The object was to develop an algorithm to dynamically determine optimal test station loading, that is, the sequence in which parts should be tested and retested so that the average turn-around time is a minimum. The AML team formulated the problem as a linear programming model and developed a software package to solve the model.

1983-84

THE COLLECTION OF CANCELED CHECKS FOR PROCESSING
SPONSOR: Union Trust Company of Maryland
Operations Center
Mr. William Dieter
Mr. William Thomas
Directors: Dr. John F. Morrison
Mr. Ernest C. Ilgenfritz

The project was a study of the routes used in the collection of canceled checks from the branch offices for processing at the main processing center. The object was to provide a steady flow of work for the employees at the processing center with minimal cost, while meeting the necessary deadlines for the transport of the checks to their issuing institutions, so that Union Trust could be credited with the corresponding funds as soon as possible. The AML team produced a set of programs which provided an approximate solution to this problem and which allowed the bank to adjust routes if the location of branches, deadlines, or other parameters changed.

1984

ACOUSTICAL PATTERN RECOGNITION
SPONSOR: A.A.I. Corporation
Mr. John Hammond
Dr. N.B. McNellis
Directors: Dr. James P. Coughlin
Dr. Jacob Huang

The project was a study of the acoustic spectra of vehicles. The objective was to develop an instrument capable of identifying vehicles by their sound waves. The AML team attempted to find correlations between amplitudes and phases of sound waves of different vehicles. These attempts proved unsuccessful, however.

1985-86 A CUSTOMER SERVICE QUEUEING MODEL
SPONSOR: Citicorp
Directors: Dr. Saeed Ghahramani
Dr. Daniel Richman

The project was to analyze the incoming calls to their Choice credit card department. The object was to determine the minimum number of operators necessary to retain at least 97.5 % of their customers, while keeping no customer on hold for more than 30 seconds. The AML team made a mathematical queueing model for the problem and found a closed form solution. The team then created a software package that solves the problem. This software package is still being used by Citicorp to schedule operators.

1986-87 ESTIMATION OF SALES TAX LIABILITY
SPONSOR: The Comptrollers Office of the State of Maryland
Directors: Mr. Howard Kaplon
Dr. William Link

The project is a study of a sampling and estimation problem for the Retail Sales Tax Division of the Comptrollers Office of The State of Maryland. The Retail Sales Tax Division audits large businesses for the purpose of determining whether the correct amount of sales tax has been submitted to the state. The AML team has determined statistical schemes for sampling invoices and derived several new techniques for estimating the total sales tax liability of the audited concern. These techniques have smaller errors of estimation than the standard methods now in use by most auditing firms.

1988-89 STATISTICAL SURVEYING OF LONG-TERM CARE PATIENTS IN NURSING HOMES IN THE STATE OF MARYLAND
SPONSOR: Blue Cross-Blue Shield of Maryland
Directors: Dr. Edward Danial
Dr. Saeed Ghahramani

The project is a study of nursing homes in Maryland for the purpose of determining actuarial tables for length-of-stay at such facilities. Factors affecting length-of-stay will be studied as well.